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Insect and Disease Conditions of Pinyon Pine and Utah Juniper in Mesa Verde National Park, Colorado

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Rocky Mountain Region

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ABSTRACT

Insects and diseases have significant impacts on pinyon pine and Utah juniper within Mesa Verde National Park. The major problem is the black stain root disease (*Verticicladiella wagenerii*) on pinyon pine. The disease is widespread throughout the Park and at least 175 active disease centers have been located from the air. Many more centers with older mortality are apparent. Insects are probably vectors of the fungus; however, specific relationships are yet to be elucidated. Other pinyon and juniper insects and pathogens present in the Park are discussed relative to their abundance, distribution, and importance.

INTRODUCTION

At the request of the National Park Service, current insect and disease conditions of pinyon pine (*Pinus edulis* Engelm.) and Utah juniper (*Juniperus osteosperma* (Torr.) Little within Mesa Verde National Park were investigated. The purpose of this investigation was to identify insects and disease-inciting pathogens and evaluate their current and potential impact on the resource.

Mesa Verde National Park is located in extreme southwestern Colorado. It was established in 1906 and contains 21,000 hectares (52,000 acres). Elevations vary from nearly 2200 meters (7000 feet) at the Park entrance to more than 2600 meters (8500 feet) at the highest point.

The vegetative composition throughout the Park depends primarily upon the occurrence of natural fire. Most of the plateau areas contain forests of pinyon pine and Utah juniper. However, dense brush vegetation is common at higher elevations.

Studies (2, 3) indicate that fires throughout previous centuries have permitted chaparral-like vegetation to persist as a fire climax along the uplands of the Park. Plant succession following fire proceeds rapidly from a pioneer stage of shade intolerant weeds to a meadow stage dominated by native grasses. After about 25 years, brush becomes the dominant vegetation. Major brush species include Gambel oak (*Quercus gambelii* Nutt.), big sagebrush (*Artemisia tridentata* Nutt.), and bitterbrush (*Purshia tridentata* (Pursh) D.C.). At the time of brush dominance, pinyon pine and Utah juniper seedlings become established. The shrub community gradually becomes more dense and in about 100 years forms

a thicket stage. Young trees develop through the shrubs, eventually overtopping them. As the site proceeds toward a climax condition, the brush species are gradually suppressed by the maturing forest. Under the present management policies of fire suppression within the Park, thick pinyon-juniper forest has become the major vegetation type (2, 3).

National Park Service management goals for Mesa Verde have been traditionally geared toward preservation of the archeological resources with less emphasis on vegetation management. A major concern of personnel has been that of strict fire control for the purposes of visitor safety and preservation of improvements and existing artifacts. Recently, however, concern has been expressed about the rapid decline of pinyon pine within the Park.

This decline, which is characterized by dying of trees in groups, was first discovered by J. L. Mielke (Forest Service, Plant Pathologist) and S. T. Carlson (National Park Service) in 1942 (14). During study of the disease complex, a fungus originally assigned to the genus *Leptographium* was considered the primary cause of pinyon pine mortality. Subsequent work has resulted in renaming the causal organism *Verticicladiella wagenerii* Kendrick (9). Mortality due to this disease has continued with resulting large centers of mortality throughout much of the Park.

Verticicladiella wagenerii is an important root pathogen of conifers which seems to be limited to western North America. In addition to *Pinus edulis*, it has been reported on singleleaf pinyon (*P. monophylla* Torr. and Frem.) in California and Nevada (13); on knobcone pine (*P. attenuata* Lemm.), jeffrey pine (*P. jeffreyi* Grev. and Balf.), sugar pine (*P. lambertiana* Dougl.), western white pine (*P. monticola* Dougl.), and ponderosa pine (*P. ponderosa* Laws.) in California (12, 13); on Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) in California, Oregon and Washington (1, 8, 13); and on eastern white pine (*Pinus strobus* L.) and lodgepole pine (*P. contorta* Dougl.) in Montana (11, 15).

Early symptoms of this disease include reduction of terminal growth, needle chlorosis, and reduced needle length and retention. The crown becomes thin and yellow, a condition also symptomatic of other root diseases. In 1 to 8 years after symptoms first appear, terminal growth stops, and the tree dies (7, 13, 14).

A cross section of an infected stem or root reveals that the pattern of stain is not wedge shaped as in most blue stains, but tends to occur in arcs that parallel the annual rings (Fig. 1). Most blue stain fungi concentrate in the medullary rays and advance along them, whereas *V. wagenerii* progresses through the tracheids and is not found in the ray parenchyma (13).

FIGURE 1 Cross-sectional pattern of black stain caused by *Verticicladiella wagenerii* on *Pinus edulis*. The fungus progresses through wood tracheids to form arcs that parallel the annual rings.

FIGURE 2 *Verticicladiella wagenerii* disease center in *Pinus edulis*. The fungus spreads from one infected tree to another via root contact to form centers of mortality.

The pathogen causes a wilt-type disease and is restricted to the tracheids of the xylem cylinder. When the tree dies the fungus can be isolated from the cambial layer of the inner bark (7, 12, 13).

In established infection centers, the disease spreads from one host to another by means of root contacts or grafts (13). As each new host is contacted, it becomes infected and eventually dies. The circle of dead and dying trees enlarges as a result, with the recently infected and dying trees on the periphery of the infection center (Fig. 2).

The establishment of new infection centers is not clearly understood. There is evidence that insects, particularly root-feeding beetles, may be involved as vectors of the fungus (4).

Mesa Verde National Park administrators have expressed desire to know extent, distribution, and biological associations of the disease. Aerial and ground reconnaissance was conducted to provide some of this information. In addition, general observations of insects and other diseases on forest vegetation were made.

METHODS

Aerial reconnaissance of the Park was conducted to locate and map active mortality centers, i.e., those with recently killed pine as evidenced by red foliage. Active centers were located on 1:24,000 aerial photo composite maps, and delivered to the National Park Service (NPS) office on May 11, 1978. Areas mapped were bordered by Whites and Wild Horse Mesas on the east and west respectively, the National Park boundary on the south, and the pinyon-juniper type on the north. A total of approximately 11,300 hectares (28,000 acres) were mapped.

Active mortality centers were examined on the ground. Xylem tissue at the root collar of fading trees was examined for presence of the characteristic black stain of *V. wageneri*. In some small infected trees, lateral roots were excavated and the black stain traced to its origin. Associated insects were collected and identified.

A number of plots were located in active centers of infection at widely dispersed sites throughout the Park to evaluate rate of spread of black stain root disease. In each plot a tree was established as plot center and all other plot trees referenced to this center by azimuth and distance. Each live plot tree greater

than 13.7 m (4.5 ft) height was numbered (metal tag), measured (DBH, height) and given one of the following disease ratings:

Rating	Description of Foliage
1.	No chlorosis; tree foliage appears normal green color.
2.	One-third of the crown displays chlorotic foliage (based on number of affected branches). This chlorosis need not be restricted to any portion of the crown.
3.	Two-thirds of the crown displays chlorotic foliage.
4.	All crown branches exhibit chlorotic foliage (general yellowing throughout the crown). May have some isolated red/brown foliage.
5.	Crown with red/brown foliage remaining on twigs; tree dead.
6.	Black - all or most of foliage gone; standing tree.

Each symptomatic tree was also examined for presence of *V. wageneri* at the root collar. Plots were delimited on the basis of patterns of symptomatology. At least one tier of green, non-symptomatic trees were included on plot margins.

RESULTS

Approximately 175 active black stain root disease centers were located within Mesa Verde National Park from the air. There were many more older, apparently inactive centers within the Park. Centers varied in size from one or two trees to several acres. Active disease centers were widespread throughout most of the Park with highest densities occurring on portions of Park and Moccasin Mesas. On these mesas, numerous centers were found near bordering canyons. There were also many active centers near areas of concentrated public use on Chapin and Wetherill Mesas. Most pinyon pine areas within the Park had high disease incidence.

Ground checks confirmed the presence of *V. wageneri* in declining trees. The fungus was readily seen in root collar xylem of trees in early stages of decline; i.e., chlorotic foliage was present. As trees died, with resultant reddening of foliage, blue stain

fungi introduced by insects often masked the stain produced by *V. wageneriii*. Examination of trees in the early stages of decline was important for proper identification of the causal organism.

Roots of declining trees had the characteristic black stain with abundant resinosis near margins of the stain (Fig. 3). In small lateral roots (1-3 cm in diameter) the black stain often completely impregnated xylem tissues.

The development of infection centers at Mesa Verde was similar to that described by other investigators (8, 10, 12). In some older centers, the fungus appeared to be inactive, since no recent mortality was present.

In 1944 J. L. Mielke established a plot to study *V. wageneriii* infection center development. It is located about 3.8 km (2.4 miles) north of Park Headquarters just west of the Chapin Mesa road. Initially, a total of 73 live pinyon trees within 334.6 m^2 (3600 sq ft) were located within the study plot. Trees were tagged and referenced on a map. Periodic inspections during the past 34 years have revealed trends of mortality. Currently 17 of the original 73 trees are still alive and no new mortality has been detected during the past 5 years. Pinyon reproduction not present when the plot was established has been tagged and mapped for future observation. Currently, 53 seedlings/saplings over 30.5 cm (12 inches) in height and 26 seedlings less than 30.5 cm (12 inches) are present on the plot. To date, none of this reproduction has exhibited typical disease symptoms.

Trees affected by black stain root disease were often infested by pine engraver bark beetles (*Ips confusus* Le Conte). In other portions of the West, bark beetles are commonly found in trees infected with *V. wageneriii*. For example, in the Sierra Nevada Mountains of California, western pine beetle (*Dendroctonus brevicomis* Le Conte) and red turpentine beetle (*Dendroctonus valens* Le Conte) are often found in trees with black stain root disease (6).

Other insects observed on pinyon pine include caterpillars of the family Arctiidae, tiger moths (*Halisdota ingens* Hy. Edwards), and spindle gall midges (*Pinyonia edulicola* Gagnè). Continued light mortality of Douglas-fir, due to the Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins) was observed on the North Rim of the Park. Also tent caterpillar larvae (*Malacosoma californicum* (Packard)) were observed on bitterbrush and snowberry.

Dwarf mistletoe (*Arceuthobium divaricatum* Engelmann) was found on pinyon pine near the north entrance to the Park (Fig. 4). This parasite was not located in other portions of the park. Some

FIGURE 3 Patterns of black stain in *Pinus edulis* root colonized by *Verticicladiella wagenerii*. Heavy resin impregnation usually precedes invasion of wood tissues by the fungus.

FIGURE 4 Dwarf mistletoe (*Arceuthobium divaricatum*) on *Pinus edulis* near the north entrance to Mesa Verde National Park. Mortality of trees with multiple infections was often hastened by attack from pine engraver beetles.

mortality due primarily to attack by bark beetles (*Ips* spp.), was associated with dwarf mistletoe. Examination of trees infected with dwarf mistletoe failed to reveal associations with black stain root disease.

Two diseases of Utah juniper were common and widespread throughout the Park. The first, true mistletoe caused by the parasite *Phoradendron juniperinum* subsp. *juniperinum* Wiens (Fig. 5), was found in many areas and was especially important in trees near permanent structures, such as Park headquarters. In general, true mistletoe infection was having little impact on trees. However, in a few cases, some mortality resulted from trees with multiple infections. The other disease noted on juniper was cedar-apple rust caused by the fungus *Gymnosporangium juniperi-virginianae* Schw. (Fig. 6). The rust was causing little injury to juniper. Occasional "galls" were formed on infected branches. These galls were often attacked by secondary fungi which killed host tissue with resultant necrosis of distal portions of infected branches. This rust is generally less of a problem on juniper than on its alternate hosts (Malaceae).

Seven study plots were established during the 1978 field season. Table 1 summarizes tree information for these study plots. Descriptions of plot locations and characteristics are included in the Appendix.

DISCUSSION

Black stain root disease is a major factor influencing pinyon pine stands in Mesa Verde National Park. The disease is causing mortality throughout the Park, and has reduced the number of large pinyon pine in some areas. In many infection centers, however, adequate pine reproduction is becoming established within openings created by the disease. Much of this reproduction may become infected when their root systems come in contact with those of previously infected trees. Based on observations within the Park and elsewhere, infection centers usually stabilize after a few years even though there may be additional host material available for infection. Reasons for such stabilization are unclear. Some evidence (4) indicates that infected root systems are usually invaded by secondary fungi which may eventually replace *V. wageneriі*. Also, root contact necessary for spread may not occur.

FIGURE 5

True mistletoe (*Phoradendron juniperinum* subsp. *juniperinum*) on *Juniperus osteosperma*. The parasite is generally non-destructive although trees with multiple infection may be killed.

FIGURE 6 Cedar-apple rust (*Gymnosporangium juniperi - virginanae*) on *Juniperus osteosperma* - Orange fruiting structures called "cedar apples" produce telial horns which give rise to wind-borne sporidia. Sporidia then infect alternate hosts (Malaceae).

TABLE 1. Summary of black stain root disease plots established in 1978 at Mesa Verde National Park.

	Number of trees [1]						
Plot/Disease Class	1	2	3	4	5	6	Live trees with V. w.
Tunnel # 1	16	1	3	1	0	2	4
Tunnel # 2	13	1	1	1	1	3	2
Wetherill # 1	43	4	8	0	1	24	8
Wetherill # 2	75	1	2	1	2	9	3
Moccasin # 1	50	1	1	1	0	0	2
Moccasin # 2	101	3	8	1	40	29	8
Chapin # 2	15	0	2	0	0	1	2
Totals	313	11	25	5	44	68	29
Percent #1 [2]	67.2	2.4	5.4	1.1	9.4	14.6	-
Percent #2 [3]	88.4	3.1	7.1	1.4	-	-	8.2 %

[1] Includes tagged trees and brown and black trees over 4.5 feet tall.

[2] Percentage of all trees (alive and dead)

[3] Percentage of Live trees (tagged) only.

Total Trees Tagged = 354

Total trees in plots (exclusive of seedlings) = 466

Individual disease center stabilization may have little effect on overall disease epidemiology because of the rapidity of new center establishment. Based upon biological characteristics of the fungus and evidence from previous investigations (4), it is likely that insects play an important role as fungal vectors. Spores of the fungus are produced in a sticky matrix often within or adjacent to bark beetle galleries (5). Insects could likely carry the fungus upon emergence. No cost - effective way of limiting spread of the fungus within existing centers is currently available.

The long-term effect of black stain root disease on pinyon-juniper stand composition is unknown. Older pinyon pine are being killed in large numbers. However, in the areas surveyed, juniper does not appear to be increasing significantly. Rather, young pinyon pine are invading the openings. Therefore, the ratio of pinyon to juniper may not be significantly changed.

The major impact of the disease may be the buildup of fuels. Since wood from dead trees deteriorates slowly in pinyon-juniper ecosystems (2), fuels continue to accumulate in the presence of black stain root disease. This fuel buildup is a definite fire hazard.

Some work has been done to control black stain root disease under natural forest conditions. Usually, all infected trees within disease centers plus an additional buffer of uninfected trees were removed to prevent spread via root contact. Because of the suspected limited viability of the fungus in infected root systems, this procedure may be effective. However, Jackman and Hunt (8) found that removal of only a single ring of healthy trees around infection centers was not enough to limit disease spread.

This approach to disease control within most of Mesa Verde National Park is not feasible because of the large number of existing centers. In areas of concentrated public use where dead trees are hazardous, it is desirable to remove these trees.

It is important to monitor mortality due to black stain root disease in different portions of the Park to better understand future potential impacts of the disease. Although the J. L. Mielke study plot provides some information, we need to monitor disease development in additional areas to elucidate overall effects. Therefore, seven more study plots were established to provide such information as (1) rate of disease spread over time, (2) length of time required for tree mortality, and (3) disease center stabilization characteristics.

Additional work is also needed to fully understand the biology of *V. wageneriii* on pinyon pine. In particular, information is needed

on insect/pathogen relationships. For example, we need to understand the role of insects in new infection center establishment. We also need information on the persistence of the pathogen in infected root systems. This information would be useful to predict infection hazard to pine reproduction. When a more complete understanding of the biology of *V. wageneri* is available, we will be in a better position to cope with and reduce losses from this disease.

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APPENDIX

Black Stain Root Disease Study Plots

Plot: Chapin # 2

Location: Chapin Mesa; 1.6 km (1.0 miles) north on main surfaced road from junction of road to Park Headquarters and Ruins Road. West side of road is a dirt road with locked gate. Plot is 300 meters (15 chains) west from the gate on left side of dirt road.

Number of Tagged Trees: 17

Tag Numbers: 103 - 119

Seedlings: 1

Disease Classes:	No. Trees
1	15
2	0
3	2
4	0
5	0
6	1

Plot: Tunnel # 1

Location: Near North Rim; 1.6 km (1.0 miles) west of tunnel on main surfaced auto road on north side of road (uphill).

Number of Tagged Trees: 22

Tag Numbers: 625 - 646

Seedlings: 6

Disease Classes:	No. Trees
1	22
2	1
3	3
4	1
5	0
6	2

Plot: Tunnel # 2

Location: Near North Rim; 1.4 km (0.9 miles) west of tunnel on main surfaced auto road on north side of road (uphill).

Number of Tagged Trees: 17

Tag Numbers: 283 - 299

Seedlings: 0

Disease Classes:	No. Trees
1	13
2	1
3	1
4	1
5	1
6	3

Plot: Moccasin # 1

Location: Moccasin Mesa; 3.7 km (2.3 miles) south on Moccasin Mesa Road (Dirt). Plot on east side of road.

Number of Tagged Trees: 53

Tag Numbers: 120 - 172

Seedlings: 0

Disease Classes:	No. Trees
1	50
2	1
3	1
4	1
5	0
6	0

Plot: Moccasin # 2

Location: Moccasin Mesa; 5.3 km (3.3 miles) south on Moccasin Mesa Road (dirt). Plot on east side of road.

Number of Tagged Trees: 113

Tag Numbers: 173 - 200
2 - 21
59 - 100
602 - 624

Seedlings: 55

Disease Classes:	No. Trees
1	136
2	3
3	8
4	1
5	47
6	41

Plot: Wetherill # 1

Location: Wetherill Mesa: 0.2 km (0.1 miles) southeast of paved road junction just south of Long House. Plot on north side of road.

Number of Tagged Trees: 55

Tag Numbers: 601
647 - 700

Seedlings: 189

Disease Classes:	No. Trees
1	218
2	4
3	8
4	1
5	1
6	36

Plot: Wetherill # 2

Location: Wetherill Mesa: 4.2 km (2.6 miles) south (counterclockwise) on loop south of Long House. Plot on northeast side of road.

Number of Tagged Trees: 80

Tag Numbers: 801 - 880

Seedlings: 68

Disease Classes:	No. Trees
1	137
2	1
3	3
4	2
5	3
6	12